Chapter 13 Problems

13-3 Probability = n + \( \frac{1}{5} \)

\[ = \frac{6.02 \times 10^{-23} \text{ atoms}}{238 \text{ g}} \times 19 \text{ g} \times 3 \text{ cm} \times 6 \times 10^{-6} \text{ cm}^2 = 0.08 \]

13-6 Probability = \( \frac{d\Gamma}{d\Omega} \) n +

\[ = 0.2 \times 10^{-27} \text{ cm}^2 (3 \times 10^{-8} \text{ sr}) \left( \frac{6.02 \times 10^{23} \text{ atoms}}{12.0 \text{ g}} \right) \left( 1.00 \times 10^{-6} \text{ cm}^2 \right) \]

\[ = 3.0 \times 10^{12} \text{ Probability of producing a proton} \]

Now if the current is \( 0.2 \times 10^{-6} \text{ A} \)

Incident particles = \( 0.2 \times 10^{-6} \text{ Coul} \)

\[ = 1.6 \times 10^{-19} \text{ Coul} \left( \frac{1}{1.6 \times 10^{-19} \text{ Coul}} \right) \]

\[ = 6.24 \times 10^{10} \text{ Particles/sec} \]

Detected particles = \( 1.8 \times 10^{-12} \) \( (6.24 \times 10^{10} \text{ Part}) \)

\[ = 1.88 \times 10^{4} \text{ Part/sec} \]

1.88 \( \times 10^{5} \) sec \[ = 6.77 \times 10^{6} \text{ Particles into our detector} \]

13-11 a) \( Q = K_x + K_y - K_z = 1.1 + 6.4 - 5.5 = 2.0 \text{ mV} \)

b) Voltage does not change! \( K_z \) goes to 10 mV, but \( K_x \) and \( K_y \) go up as well.
From classical meek, the Cofm system is equivalent to a particle of rest $M_x + M_\infty$ moving with speed $V_{\infty}$. So the C of m kinetic energy is

$$K_{em} = \frac{1}{2} (M_x + M_\infty) V_{\infty}^2 \quad \text{CII} \quad M_x + M_\infty \equiv M$$

Then: \[ M V_{em} = M_x V_x \] (total mom in lab)

So \[ V_{em} = \frac{M_x}{M} V_x \]

\[ K_{em} (c Clem) = \frac{M V_{em}^2}{2} = \frac{1}{2} \frac{M_x^2}{M} V_x^2 \]

This is the $\frac{1}{2} k$ of the eg as seen in the lab.

Available energy in the Cofm = $K_{lad} - K_{em}$

\[ K_{em}' = \frac{M_x V_x^2}{2} - \frac{M_x^2 V_x^2}{2 M} = \frac{M_x V_x^2}{2} (1 - \frac{M_x}{M}) \]

\[ K_{em}' = K_{lad} \left( \frac{M_x}{M_x + M_\infty} \right) \quad \text{aqd} \quad (13.11) \]

N.b. this is necessarily less than $K_{lad}$ since some energy must be available for motion to conserve momentum.

This is maximized when $M_x / M_\infty \ll 1$ (heavy targets, light bullets) since then is little recoil.

N.b. we have solved this whole problem relativistically with the use of invariants.
\[ t = \frac{13.2}{\ln 2} = \frac{1.09 \times 10^{-3}}{\ln 2} = 157 \text{ m sec} \]

\[ \Gamma = \frac{1}{2} \text{ uncertainty value} \]

\[ \gamma = \frac{t}{2 \tau} = \frac{6.58 \times 10^{-14} \text{ eV} \cdot \text{sec}}{2(1.57 \times 10^{-13})} = 2.1 \times 10^{15} \text{ eV} \]

\[ ^{11} \text{B}_t \text{ can decay via } \beta^+ \text{ or } \nu^+ \text{ capture.} \]

13-27 c) \[ M = 4 \times 10^{-4} \times 10^6 \text{ kg} = 400 \text{ kg} \]

b) \[ 600 \text{ kg} \times \frac{6.02 \times 10^{23} \text{ atoms}}{2.38 \text{ g}} = 1.0 \times 10^{27} \text{ atoms} \]

c) \[ 69 \text{ fission } \times 1000 \text{ ks} = 276 \text{ Bq} \]

d) \[ 276 \text{ Bq} \times 86400 \text{ s} = 2.38 \times 10^7 \text{ fissions/day} \]

13-30 \[ 10^8 \text{ MeV} = 10^9 \text{ } \frac{1}{\text{sec}} \times \frac{86400 \text{ sec/day}}{1.6 \times 10^{-13} \text{ J/MeV}} = 5.4 \times 10^{24} \text{ MeV/day} \]

\[ 5.4 \times 10^{24} \text{ MeV/day} \times \frac{1 \text{ fission}}{200 \text{ MeV}} = 2.7 \times 10^{24} \text{ fissions/day} \]

\[ 2.7 \times 10^{24} \text{ atoms/day} \times \frac{1.238 \text{ ks}}{6 \times 10^{23} \text{ atoms}} = 1.1 \text{ ks/day} \]
13-44 \( \frac{R}{R_0} = \frac{5.12}{60} = 8.52 \) Bq in oil today.

\( R_0 = 4 \times 10^5 \) Bq 60 days ago for VL whole mass.

Today the entire mass would have an activity

\( R' = R_0 e^{-\lambda t} + 60 \sec \)

Since \( R = \lambda W \), the fraction in the oil
now is just

\[ \frac{R'}{R_0} = \frac{5.12}{4 \times 10^5} \]

\[ \frac{R'}{R_0} = 5.43 \times 10^{-5} \) in VL fraction by vol.

13-43 \( I = (15) (4 \times 10^5 \text{ sec}^{-1}) (2) (1.6 \times 10^{-19}) \) = 1.9 \times 10^{-14} \text{ A}

1) \( 10^{-7} \) of the above \( 1.9 \times 10^{-15} \text{ A} \) !

14-42 From 14.32 \( \frac{dE_x}{dx} \propto E^2 \)

Comparing to a proton with \( E = 1 \), each \( x \) will have \( E^2 \) times the stopping power.

\[ \frac{dE_x}{dx} = \frac{E^2_p}{dx} \]

in general \( E = \frac{1}{2} m v^2 \) so \( v^2 = \frac{2E}{m} = 2E_p / m_p \)

so \( E_p = \left( \frac{m_p}{m_x} \right) E_x \)
14-43  a) \( 28 \text{ keV/mg cm}^2 \times (19.8 \text{ g/cm}^3) = 5.32 \times 10^5 \text{ keV/cm} \)
\[ E_L = \frac{m_e}{m_p} E_0 = 4.5 \text{ MeV} = 20 \text{ MeV} \]
\[ T = 2 \text{ for } \alpha \text{ so } \frac{dE}{dx} = 4 \times (53.2) = 213 \text{ MeV/ mm} \]

14-44  a) \( P = 0.12 \frac{g}{cm^2} \left( \frac{1.0 \text{ cm}^3}{11.35 \text{ g}} \right) \frac{10 \text{ mm}}{\text{cm}} = 0.16 \text{ mm} \)

b) \( P = 5 \frac{g}{cm^2} \left( \frac{1}{11.35} \right) 10 = 4.4 \text{ mm} \)

c) \( P = 250 \frac{g}{cm^2} \left( \frac{1}{11.35} \right) 10 = 220 \text{ mm} \)

Note how distance goes up fast than the scaling with energy.

14-49  \( I = I_0 e^{-\mu x} = 10^{-6} \text{ } \) as \( \mu x = -\ln 10^{-6} = 6.8 \)

From \( \mu x = 0.07 \text{ cm}^2/\text{g} \)
\[ \mu \frac{13.5}{0.07 \text{ cm}^2/\text{g}} = 197 \text{ g/cm}^2 \]
\[\frac{197 \text{ g/cm}^2}{11.35 \text{ g}} = 17.4 \text{ cm} \text{ pretty thick!} \]
14-53 Generally \( I = I_0 e^{-\frac{t}{\lambda}} \)

For 0.2 mV, \( \lambda = \frac{2 \text{ cm}^2}{6.15 \times 10^7 \text{s}} = 22.7 \text{ cm}^2 \)

\[ I/I_0 = e^{-22.7} = 1.39 \times 10^{-10} \]

For 1 mV, \( \lambda = \frac{0.07 \text{ cm}^2}{6.15 \times 10^7 \text{s}} = 0.795 \text{ cm}^2 \)

\[ I/I_0 = e^{-0.795} = 0.45 \]

Population \( \frac{1}{\lambda} = \frac{1.39 \times 10^{-9}}{0.45} = 3.1 \times 10^{-10} \text{ mV/s} \)

13-53 \( n(\text{Uk}) = 70 \text{ kg} \left( 3.5 \times 10^{-3} \right) \left( 1.2 \times 10^{-4} \right) = 2.94 \times 10^{-2} \text{ g} \)

\[ N = 2.94 \times 10^{-2} \text{ g} \left( 6 \times 10^{23} \right) = 4.42 \times 10^{20} \text{ Atoms} \]

\[ R = \frac{1}{\lambda} N \cdot \frac{6}{40} \left( 4.42 \times 10^{20} \right) = 7584 \text{ Bq} \]

\( 7584 \text{ Bq} \left( 1.893 \right) = 6770 \text{ Bq} \)

b) 0.5 mV \((6770 \text{ Bq}) \left( 3.15 \times 10^{-9} \text{ yr}^{-1} \right) \left( 1.6 \times 10^3 \text{ J/mW} \right)

\[ \text{Absorbed Dose} = \frac{0.5171 \text{ J}}{70 \text{ kg}} = 2.44 \times 10^{-4} \text{ Gy} \]